Selection of Tau Leptons with the CDF II Trigger System

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In Run II of the CDF experiment, traditional dilepton triggers are enriched by lepton (e or μ) plus track, di-τ and τ plus missing transverse energy triggers at Level-3 dedicated to physical processes including tau leptons. We describe these triggers, along with their physics motivations, implementation and cross-sections and report on their initial performance.

1. Introduction

Run II of the Tevatron produces $p\bar{p}$ interactions with an instantaneous luminosity about 10^{32} cm^{-2} s^{-1}. The CDF Detector trigger system [1] decreases the resulting initial event rate of 2.5 MHz down to 70 Hz for data storage and offline analysis, with the goal of efficient extraction of interesting physics events from the large minimum bias background. One important subset of these physics signatures includes τ leptons. Events with τ's are important for the study of various Standard Model (SM) processes such as $Z \to \tau\tau$, $t\bar{t}$ with $W \to \tau\nu_\tau$, $H \to \tau\tau$ and also to extend the reach of searches for physics beyond the SM. These physics goals drive us to look for τ-like objects starting with Level-3 of the trigger, and our implementation selects events with two

leptons in the final state: $e\tau_h, \mu\tau_h, \tau_h\tau_h$ and also $\tau_h\nu$, as well as $ee, e\mu$ and $\mu\mu$. With "τ_h" we indicate hadronically decaying τ's, while the e or μ can be either produced directly or through a leptonic decay of the τ.

These tau triggers benefit from the upgraded CDF trigger system, in particular the tracking processor at Level-1 (L1) and the refined tracking information available at Level-2 (L2) [1,2].

2. Implementation of the τ Triggers

2.1. τ reconstruction

Taus promptly decay in leptonic or hadronic (65%) modes with at least one ν in the final state. Hadronic τ decays have the distinct signature of a narrow isolated jet with low multiplicity (1 or 3 prongs) and low visible mass ($< M_\tau$). The basis for our triggers, therefore, is a τ-cone algorithm for the reconstruction of these decays. To

build the τ-cone object, we start with a narrow calorimeter cluster, above a suitable E_T threshold, matched to a seed track with momentum above a P_T cut. The region within an angle Θ_{Sig} from the seed track direction is used to define a cone of tracks to be associated with the τ. The region between Θ_{Sig} and Θ_{Iso} defines the isolation cone: we require that no tracks with P_T higher than a fixed low threshold be found in this region. At the Level-3 (L3) of the trigger, Θ_{Sig} and Θ_{Iso} have values of 10°, and 30°, respectively, and are determined in 3 dimensions.

We have implemented 4 different triggers for physics processes with τ's in the final state, installed in the CDF trigger tables in January 2002. Below we describe their main features.

2.2. Electron plus track, Muon plus track

The selection for the e plus track trigger starts with L1 and L2 requirements of a single EM tower with $E_T > 8$ GeV with an associated XFT track with $P_T > 8$ GeV/c and a second track with $P_T > 5$ GeV/c. At L3, these conditions are refined and charged track isolation around the reconstructed (2nd) track is imposed. The current average cross-section for this L3 trigger is $\sim$29 nb. For the muon plus track trigger we require a muon stub matched at L1 to an XFT track with $P_T > 4GeV/c$, with an increased track threshold of 8 GeV/c at L2. The "track" requirements are identical to those for the electron plus track trigger. The current average cross section for this trigger is $\sim$16 nb.

2.3. Di-τ,τ plus Missing Transverse Energy

At L1 the di-τ trigger requires 2 calorimeter towers with $E_T > 5$ GeV and 2 matching XFT tracks with $P_T > 6$ GeV/c, separated by an angle of $\phi > 30$°. L2 requires cluster $E_T > 10$ GeV and imposes track isolation. At L3, using the full reconstruction code, 2 τ candidates with seed track $P_T > 6$ GeV/c, and originating from the same vertex: $|\Delta Z| < 10$ cm, are required. The L3 cross section for this trigger is $\sim$12 nb.

The τ plus missing transverse energy (MET) trigger requires $E_{MET} >$10 GeV at L1. At L2 this is increased to $E_{MET} >$20 GeV and a calorimeter cluster with an isolated track with $P_T >$10

GeV/c is required. This is followed by full event reconstruction at L3, requiring at least one τ candidate having seed track $P_T > 4.5$ GeV/c. The present trigger cross section is 5 nb.

3. First Results

The study of $Z \rightarrow \tau_e\tau_h$ is performed using 72 pb^{-1} of data taken with the electron plus track trigger [3]. The track multiplicity associated with the τ_h candidate found in events passing selection cuts is shown in Fig. 1. We observe a clear τ signal over background levels even before requiring an opposite sign charge for the electron and the τ_h. The mass distribution of the electron-τ_h-MET system in the data is also found to be consistent with the $Z \rightarrow \tau\tau$ hypothesis.
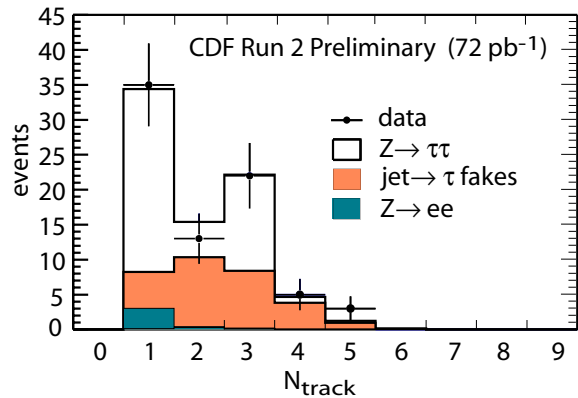

Figure 1. Track multiplicity for the τ candidate.

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